# 10. Cost and Emission Reduction Analysis of HFC Emissions from Aerosols in the United States

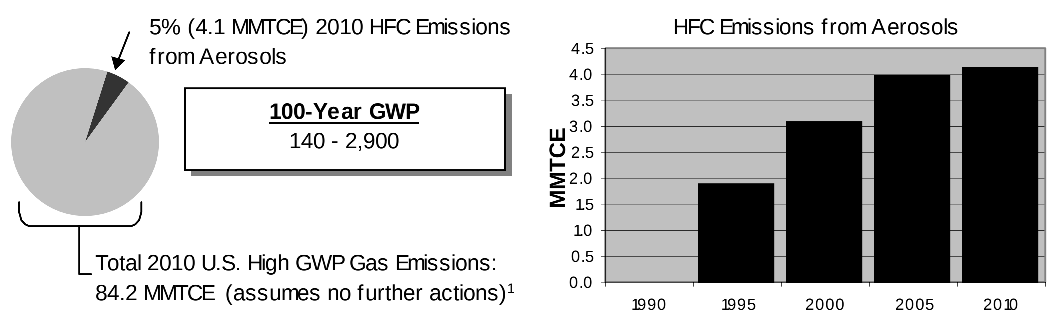
## 10.1 Introduction

Various hydrofluorocarbons (HFCs) are used as propellants in aerosol applications. These include HFC-134a, HFC-152a, and HFC-227ea, with 100-year GWPs of 1,300, 140, and 2,900 times the warming potential of carbon dioxide, respectively. Under a business-as-usual scenario, by 2010, the U.S. would be expected to emit over four MMTCE of these HFCs from the use of aerosols if further reduction efforts are not made (see Exhibit 10.1).[1]

Metered dose inhalers (MDIs) will account for one-third of all aerosol HFC equivalent emissions by 2010, representing about 1.4 MMTCE. Inhaled therapies, primarily MDIs, are critically important in the treatment of asthma and chronic obstructive pulmonary disease (COPD), each affecting millions of Americans (American Lung Association, 2000). Historically, the majority of MDIs have used CFCs as the propellant. However, as a result of initiatives under the Montreal Protocol on Substances that Deplete the Ozone Layer and the subsequent phaseout of CFC production under the Clean Air Act in 1996, pharmaceutical companies that produce MDIs have committed to develop alternatives to CFC-based MDIs. Despite these commitments, EPA estimates that over 90 percent of the MDI industry still uses CFCs as the aerosol propellant. Because MDIs are medical devices, substitute propellants must meet far stricter performance and toxicology specifications than would be required in most other end products. Further, each MDI that is re-formulated with an alternative propellant must be approved by the Food and Drug Administration prior to entering the market.

The pharmaceutical aerosol industry currently is working to develop HFC-propellant metered dose inhalers. The earliest non-CFC substitute products, two of which earned FDA approval before January 2001, use HFC-134a, but eventually the industry expects products to utilize HFC-227ea, as well. In addition to MDIs that

**Exhibit 10.1: U.S. Historical and Baseline HFC Emissions from Aerosols**




[1] An explanation of the business-as-usual scenario under which baseline emissions are estimated appears in the Introduction to the Report.

use propellants, dry powder inhalers (DPIs) can be used as a substitute for some MDIs. However, DPIs can replace only a small portion of the market.

In addition to metered dose inhalers, HFC aerosols are becoming more widely used in various consumer products and specialty market applications. After the CFC aerosol ban in 1977, many consumer products such as spray deodorants and hair sprays were either reformulated with hydrocarbon propellants or replaced with not-in-kind substitutes such as pump sprays or solid and roll-on deodorants. Now, with the advent of HFC propellants, particularly HFC-152a, chemical manufacturers are marketing HFCs for use in consumer products. HFC-152a is preferred over HFC-134a due to its lower cost and GWP, but HFC-134a is still used in nearly half of the non-MDI aerosol market, in niche specialty markets such as electronic equipment dusters, boat and safety “air” horns, and tire inflators (Dieckmann and Magid, 1999). In general, HFCs hold a small share of the consumer aerosols market, concentrated mostly in applications where volatile organic compound (VOC) emissions and their impact on urban air quality are a concern. The aerosols industry has a strong incentive to use HFCs responsibly. If HFC use is accelerated, increased public concern may be result (UNEP, 1999).

## 10.2 Historical and Baseline HFC Emission Estimates

EPA uses a detailed Vintaging Model of ozone-depleting substance (ODS) containing equipment and products to estimate the use and emissions of various ODS substitutes. The model tracks the use and emissions of various compounds for the annual “vintages” of new equipment that enter service in each end-use. (See Appendix A for a full description of the Vintaging Model.) Aerosols represent one of the major end-use categories defined in the Vintaging Model to characterize ODS substitute use in the U.S. (see Exhibits 10.2 and 10.3). There are several regulatory programs in place (e.g., Significant New Alternatives Policy Program determines the acceptability of substitutes to ODS) to limit use of ODS substitutes in some applications. These actions are expected to result in significant reductions in ODS substitute emissions. These reductions are incorporated in the baseline estimate of emissions. The cost analysis presented here evaluates the cost of reducing emissions from this baseline.

**Exhibit 10.2: Historical U.S. HFC Emissions from Aerosols (1990-1999)**

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Emissions (MMTCE)** | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | 1.9 | 2.1 | 2.5 | 2.6 | 2.9 |

Source: EPA, 2000 (for 1990-1998) and EPA estimates (for 1999).
Notes:
Emissions are not broken down by chemical to avoid disclosure of confidential business information.
Conversion to MMTCE is based on the GWPs listed in the Introduction to the report.
The sudden increase in MMTCE is because HFC-134a began to penetrate the non-MDI aerosol market in 1994-1995.

**Exhibit 10.3: Baseline U.S. HFC Emissions from Aerosols (2000-2010)**

| | 2000 | 2005 | 2010 |
|---|---|---|---|
| **Emissions (MMTCE)** | 3.08 | 3.95 | 4.10 |

Notes:
Forecast emissions are based on a business-as-usual scenario, assuming no further action.
Emissions are not broken down by chemical to avoid disclosure of confidential business information.
Conversion to MMTCE is based on the GWPs listed in the Introduction to the report.

Non-MDI use accounts for the majority of the HFC-134a emissions (mainly for specialty end uses) and all of the HFC-152a emissions (mostly formulated consumer products), while MDI use accounts for all emissions of HFC-227ea. The estimates presented in Exhibit 10.3 were developed with the following major assumptions:

- Penetration of HFCs into the MDI end use;
- Continued growth of HFC-134a use in specialty markets; and
- Minimal impact of penetration of additional HFCs into consumer end use applications.[2]

## 10.3 HFC Emission Reduction Opportunities

### *Metered Dose Inhalers*

As MDIs are transitioned away from use of CFCs, both HFC propellants and dry powder inhalers are being developed. Although hydrocarbons have replaced CFCs as propellants in many commercial aerosols, they have been found to be unacceptable for use in MDIs (IPAC, 1999). Dry powder inhalers (DPIs) have been successfully used with most anti-asthma drugs, although they are not successful with all patients or all drugs. Micronised dry powder can be inhaled and deposited in the lungs from DPIs as with MDIs, but only in patients who are able to inhale robustly enough to transport the powder to the lungs. DPIs are not suitable for persons with severe asthma or for young children. Unlike MDIs, powdered drug particles contained in DPIs tend to aggregate and may cause problems in areas with hot and humid climates (March Consulting Group, 1999). In 1999, DPI usage in the United States was estimated to represent less than two percent of all inhaled medication. However, DPIs may represent a viable alternative, as suggested by their increased use in Europe, for example in Sweden, where they account for 85 percent of inhaled medication. Globally, DPIs are estimated to be growing at a rate of 15 percent annually. Even with anticipated strong market growth, however, DPI use will still be less than MDI (combined HFC and CFC) use in 2005 (UNEP, 1999). There is a trend towards development of a broad range of novel oral treatments that would be swallowed, rather than inhaled, and may be introduced over the next 10 to 20 years. These new medications may impact MDI use although it is not expected that they would completely replace inhaled MDI therapy.

It is important to note that the type of propellant used in MDIs is a medical decision involving the pharmaceutical industry, the FDA, and ultimately doctors and their patients who will be involved in selecting the method of therapy that proves most effective for particular individuals.

### *Specialty Products*

Specialty aerosol end-uses include tire inflators, electronics cleaning products, dust removal, freeze spray, signaling devices, and mold release agents. HFCs are currently used when flammability issues cannot easily be overcome. Examples include tire inflators and air signaling horns, that use HFC-134a to avoid potential explosivity that could occur when using highly flammable propellants (Dieckmann and Magid, 1999). HFC-152a has been utilized in dusters since 1993 and continued substitution of HFC-134a with HFC-152a is a reduction strategy that has had significant success thus far, and is expected to continue.

### *Consumer Products*

Formulated consumer products include hairsprays, mousse, deodorants and anti-perspirants, household products, spray paints, and automotive products. Many of these products utilize HFCs in order to comply with regulations that reduce allowable VOC content. The following replacement options exist for consumer aerosol products:

---

[2] The State of California and at least eight other states are considering further limiting the use of VOCs in consumer products, in which case a subset of the aerosol market may switch to HFC propellants. However, as stated previously, the high cost of HFCs, the low GWP of HFC-152a, and the potential for consumer concerns will most likely limit this transition considerably. To the extent that this does occur, the emissions presented in Exhibit 10.3 may be slightly underestimated.

- **Not-in-kind (NIK) alternatives**. These include finger/trigger pumps, powder formulations, sticks, rollers, brushes, nebulizers, and bag-in-can/piston-can systems that could displace HFCs, and often prove to be a better and more cost-effective option than HFC-propelled aerosols. Particularly in areas where a unique HFC property is not specifically needed for a certain end-use, NIK alternatives are the best option.
- **Hydrocarbon aerosol propellants**. These are usually mixtures of propane, butane, and isobutane, and are also an inexpensive choice for propellants in consumer products. Their costs average less than one tenth the cost of HFCs. The main disadvantages of hydrocarbon aerosol propellants are flammability and VOC emission concerns. Hydrocarbons are the primary propellant in the non-MDI aerosol market and could probably hold a larger share than is forecast by the Vintaging Model. If HFC-134a and HFC-152a use could be replaced with hydrocarbon use, then reductions in greenhouse gas emissions would result.
- **Dimethyl ether.** Dimethyl ether is a flammable alternative aerosol propellant. While it is a VOC, it has excellent solvency and water compatibility.
- **Compressed gases**. Gases such as $CO_2$, $N_2$, compressed air, or nitrous oxide may be used in a few aerosol applications, but these are often less effective because the propellant pressure gradually falls as the aerosol can is emptied (March Consulting Group, 1998). However, these gases are non-flammable and do not require the use of extra explosion-proof equipment. In addition, technological improvements have been made to offset the effects of decreased pressure through innovative valve configurations and proper selection of compatible solvents (UNEP, 1998).
- **Substituting for lower GWP HFCs.** Replacement of higher GWP HFCs, such as HFC-134a, with a lower GWP HFC, such as HFC-152a, will greatly reduce emissions from the aerosols sector. HFC-152a, for instance, possesses only moderate flammability hazards and might therefore be acceptable for some applications.

## 10.4 Cost Analysis

### *Metered Dose Inhalers*

Given the unique medical requirements for developing metered dose inhalers, and the fact that the industry is just beginning to introduce HFC alternatives after investing heavily in the development of HFC technologies, an aerosol replacement for HFC-based MDIs is unlikely to be developed within the time frame of this analysis. Furthermore, the cost to develop and market FDA-approved HFC-based MDIs is expected to be very high. The industry has spent approximately $1 billion developing MDIs using HFC-134a or HFC-227ea and expects to spend more to complete the development process (IPAC, 1999). If an alternative to HFC propellants could be developed, which is uncertain, the cost would likely exceed that of the CFC phaseout for MDIs. Assuming a 20 percent market penetration in 2005, which ramps up to 100 percent of the market in 2009, the incremental cost for reducing greenhouse gas emissions from MDIs would still be in the range of hundreds of dollars per metric ton of carbon equivalent.

To the extent that health and technical concerns are adequately met, a transition of inhalation therapy away from propellant MDIs and toward NIK alternatives may occur over the next 10 to 20 years. This will provide patients with a wider variety of choices, lower overall costs of MDIs, and potential displacement of CFC use. The rapidity at which these changes will occur is contingent upon product development cycles (generally about 10 years), cost-effectiveness, and manufacturing capacity. In the United States alone, over 150 patents for new alternatives have been filed over the past 10 years (UNEP, 1999).

### *Other General Aerosols*

The most viable options to reduce HFC emissions from aerosols are hydrocarbon aerosol propellants and not-in-kind replacements. All cost analyses are based on either a four percent discount rate or an eight percent discount rate and a 10-year project lifetime. Financial assumptions and results specific to each emission reduction option are presented below. Exhibit 10.4 summarizes the potential emission reductions and associated costs of both options.

**Exhibit 10.4: Emission Reductions and Cost in 2010**

| Option | Break-even Cost ($/TCE) Discount Rate | | Incremental Reductions | | Sum of Reductions | |
|---|---|---|---|---|---|---|
| | 4% | 8% | MMTCE | Percent | MMTCE | Percent |
| Hydrocarbon Aerosol Propellants | (20.35) | (20.32) | 0.23 | 6% | 0.23 | 6% |
| Not-in-kind Replacements | (19.15) | (19.12) | 0.47 | 11% | 0.70 | 17% |
| HFC replacement | (8.14) | (8.09) | 0.82 | 20% | 1.52 | 37% |

Notes:
2010 baseline HFC emissions from aerosols equal 9,246 metric tons HFC or 4.10 MMTCE.
Conversion to MMTCE is based on the GWPs listed in the Introduction to the report.
Parentheses indicate savings.
Sums might not add to total due to rounding.

**Hydrocarbon Aerosol Propellants.** The capital costs of converting filling facilities to accept hydrocarbon propellants range from $150,000 to $1,750,000. However, since the hydrocarbon prices are generally lower than the cost of HFCs, production costs are less. While both hydrocarbon and DME aerosol propellants have already been utilized significantly, it was assumed that they could displace only 10 percent of the non-MDI HFC aerosol market, given VOC and flammability concerns. Based on these factors, in 2010 this option could reduce emissions by 0.23 MMTCE or six percent of baseline emissions at a cost savings of $20.35 per metric ton of carbon equivalent (TCE) and $20.32/TCE for four and eight percent discount rates, respectively.

**NIK Replacements.** There is significant variability in financial components of projects targeting NIK replacements for HFC-containing aerosol products. This is due to the wide range of potential aerosol and NIK product types. In the case of liquid pumps and solid applicators, capital investments are lower but material costs will be higher (UNEP, 1998). For this analysis, an incremental capital cost of $250,000 was used with annual costs estimated at around $500,000, based on an annual throughput of 10 million units. Despite the costs of this option, an overall savings of almost $4,000,000 per year would result, due primarily to the avoidance of HFC costs. It was assumed that approximately 20 percent of the non-MDI HFC aerosol market could be displaced with NIK products. Based on the above factors, NIK options can reduce emissions by 0.47 MMTCE in 2010 or 11 percent of baseline emissions at a cost savings of $19.15/TCE and $19.12/TCE for four and eight percent discount rates, respectively.

**Replacement with lower GWP HFC alternatives.** The capital costs of converting filling facilities to accept HFC-152a may range in the area of $500,000 (Lueszler, 2000). It is estimated that through its use, approximately 50 percent of the non-MDI market may be captured. Also, the lower price per pound of HFC-152a, $2.15/lb, will result in significantly lower production costs (ICF Consulting, 2000). The incremental emission reduction of this option is 0.82 MMTCE, or 20 percent of the 2010 baseline emission of 4.10 MMTCE. Based on these factors, switching to the HFC-152a option can reduce emissions at a cost savings of $8.14/TCE and $8.09/TCE for four and eight percent discount rates, respectively.

## 10.5 References


American Lung Association. 2000. *Asthma Trends in Morbidity and Mortality 2000*. (Available on the Internet at http://www.lungusa.org/data/).

Dieckmann, J., and H. Magid. 1999. *Global Comparative Analysis of HFC and Alternative Technologies for Refrigeration, Air-Conditioning, Foam, Solvent, Aerosol Propellant, and Fire Protection Applications*. Final Report to the Alliance for Responsible Atmospheric Policy. Arthur D. Little, Inc., Cambridge, MA; Reference Number 49648.

EPA. 2000. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1998.* Office of Atmospheric Programs, U.S. Environmental Protection Agency, Washington, DC; EPA 236-R-00-001. (Available on the Internet at http://www.epa.gov/globalwarming/emissions/national/download.html).

ICF Consulting. 2000. Data collected from gas suppliers, Washington, D.C., July 2000.

IPAC. 1999. *The Reformulation of MDIs*. (Available on the Internet at http://www.ipacmdi.com/ Reformation.html).

IPAC. 1999. *Ensuring Patient Care 2nd Edition* (Available on the Internet at http://www.ipacmdi.com/Ensuring.html).

Lueszler, John. 2000. Personal communication. Dupont, July 2000.

March Consulting Group. 1998. *Opportunities to Minimize Emissions of Hydrofluorocarbons (HFCs) from the European Union*. Final Report. Prepared by March Consulting Group, United Kingdom.

March Consulting Group. 1999. *UK Emissions of HFCs, PFCs, and $SF_6$ and Potential Emission Reduction Options*. Final Report. Prepared by March Consulting Group, United Kingdom.

UNEP. 1998. *Montreal Protocol on Substances that Deplete the Ozone Layer, Report of the Aerosols, Sterilants, Miscellaneous Uses and Carbon Tetrachloride Technical Options Committee: 1998 Assessment*. UNEP Ozone Secretariat, Nairobi, Kenya.

UNEP. 1999. *The Implications to the Montreal Protocol of the Inclusion of HFCs and PFCs in the Kyoto Protocol*. HFC and PFC Task Force of the Technology and Economic Assessment Panel.